2021 2030 United Nations Decade of Ocean Science for Sustainable Development

PACE: How One NASA Mission Aligns With the United Nations Decade of Ocean Science for Sustainable Development (OceanShot #1)

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ABSTRACT

The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE; https://pace.gsfc.nasa.gov) mission, scheduled for launch in January 2024, will extend the continuous high-quality ocean color, atmospheric aerosol, and cloud data records begun by NASA in the late 1990s, building on the heritage of the Coastal Zone Color Scanner (CZCS), Sea-viewing Wide Field-of-view Sensor (SeaWiFS), Moderate Resolution Imaging Spectroradiometer (MODIS), and Visible Infrared Imaging Radiometer Suite (VIIRS) (Figure 1). PACE's global hyperspectral imaging radiometer design concept will enable new discoveries in Earth's living ocean (Figure 2), such as the diversity of organisms fueling marine food webs and how aquatic ecosystems respond to environmental change. Its instrument payload (Figure 3) will also observe Earth's atmosphere to study clouds, airborne aerosol particles, and the interactions between the two. Looking at the ocean, clouds, and aerosols together will improve our knowledge of the roles each plays in our evolving planet. Other applications of PACE science data records—from identifying the frequency, extent, and duration of aquatic harmful algal blooms to improving our understanding of air quality—will result in direct economic, recreational, and societal benefits. Ultimately, by extending and expanding NASA's long record of global Earth satellite observations, the PACE mission will monitor our home planet in new and advanced ways in the coming decade.

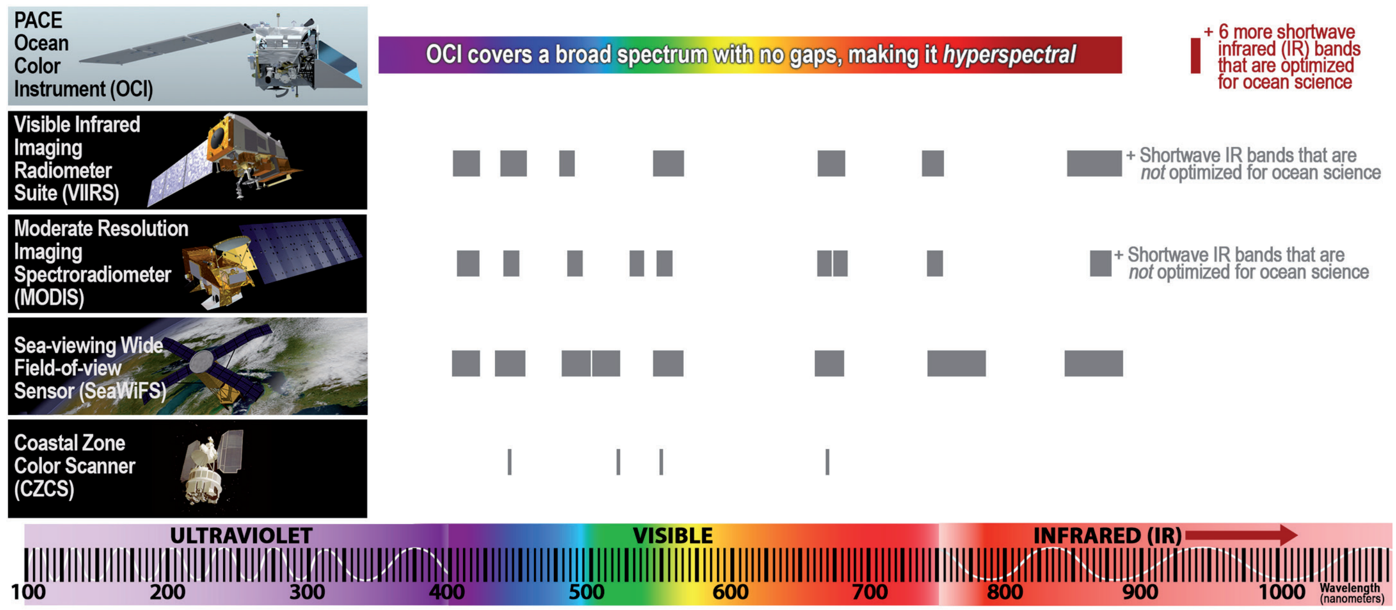

FIGURE 1. Spectral ranges covered by NASA ocean color sensors. At top, PACE's primary Ocean Color Instrument (OCI) represents NASA's move from global multispectral radiometry to spectroscopy. OCI includes spectrometers that continuously span the ultraviolet (340 nm) to near-infrared (890 nm) region in 2.5 nm steps, as well as seven discrete shortwave infrared bands from 940 to 2,260 nm. In contrast, NASA's heritage missions incorporated several discrete spectral bands placed strategically to optimize for aquatic, atmospheric, and terrestrial geophysical retrievals. VIIRS on Suomi NPP (2012 to present), MODIS on Aqua (2002 to present), and SeaWiFS (1997–2010) had seven, nine, and eight spectral bands, respectively, which were used to retrieve ocean color variables of interest and to perform ocean color atmospheric correction. The CZCS (1978–1986) was a proof-of-concept instrument that set the stage for subsequent decades of ocean color data collection.

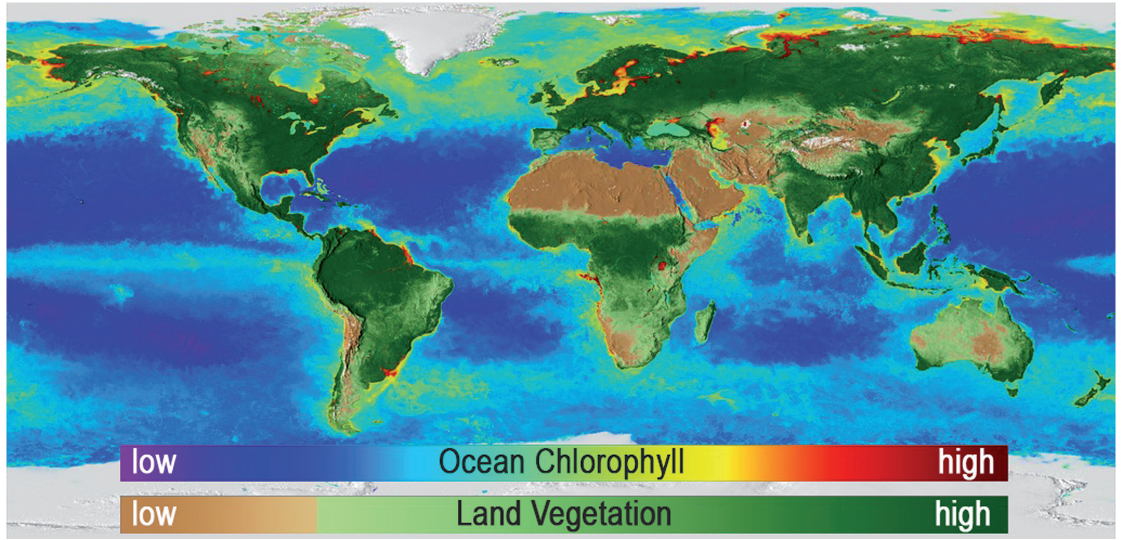

FIGURE 2. Example of global biosphere data, which has been collected continuously by NASA satellites since 1997. In the ocean, dark blue to violet represents areas where there is low biomass due to lack of nutrients, and greens and reds represent productive, nutrient-rich areas. On land, green represents areas of abundant plant life while tan and white represent areas where plant life is sparse or non-existent. (Image source: NASA Scientific Visualization Studio).

A Healthy and Resilient Ocean

A key indicator of our ocean's health is the abundance of phytoplankton in its sunlit surface layer. These tiny aquatic algae operate similar to land plants by converting carbon dioxide into cellular material while generating oxygen, thus forming the base of the marine food web and fueling ocean fisheries. For 40+ years, NASA has quantified phytoplankton abundance from space through remote-sensing estimates of the concentration of chlorophyll-a, a green photosynthetic pigment found in most phytoplankton species (Figure 2). This is possible using satellite-based measurements of the intensity of various visible wavelengths of light exiting the ocean (that is, the "color" of the ocean; Figure 1). Like on land, ocean chlorophyll patterns change over seasons, years, and decades. NASA first demonstrated the potential for satellite-derived measurements of chlorophyll-a in 1978 with the launch of its first ocean color instrument, which only collected data at a few wavelengths. As technology has progressed, newer instruments have sampled additional wavelengths, but they cannot tell the full ocean color story given spectral gaps in their sampling. PACE includes NASA's most advanced ocean color instrument ever (Figure 3), designed specifically to help identify phytoplankton community types from space, in part through its continuous spectral sampling from the ultraviolet to near infrared. By monitoring global phytoplankton distribution and abundance with unprecedented detail, PACE will help us to better understand the complex systems that drive ocean ecology and the health—and future—of our ocean and life on earth.

A Productive Ocean

The largest three-dimensional living space on earth, our ocean supports many diverse habitats. For example, the North Atlantic is home to highly productive "forests" each spring. Its blooms of carbon-rich phytoplankton fuel the fisheries of New England. The United States (U.S.) has some of the most diverse and productive ocean ecosystems in the world. According to the U.S. Global Change Research Program, the fishing sector alone contributes more than $200 billion in economic activity each year and supports 1.6 million jobs. Today's satellites reveal the quantity of phytoplankton at the ocean surface. Yet we cannot detect the diversity of species. For the first time, PACE's unprecedented technology will reveal the diversity of phytoplankton found in our ocean on global scales, and allow us to understand the role that phytoplankton diversity has on life in the ocean.

Phytoplankton distributions rapidly register impacts of environmental change, but their remotely detectable optical signals remain weak, even during periods of maximum abundance. Moving beyond heritage global ocean color remote sensing to address science questions that cannot adequately be addressed with contemporary capabilities requires high precision, well characterized radiometric instruments with high signal-to-noise measurements and expanded spectral capabilities (Figure 1). This will allow for improved assessment of phytoplankton communities and aquatic biogeochemistry, as well as accurate atmospheric correction across a wide dynamic range of optical conditions.

A Predicted Ocean

Decades of global ocean color data provide an opportunity to assess the existence of trends in phytoplankton. NASA research reveals that the world's oceans have seen significant declines in certain types of phytoplankton. Diatoms declined more than 1% per year from 1998 to 2012 globally, with significant losses occurring in the north Pacific, equatorial and north Indian oceans. Such a reduction in population may have an impact on the amount of CO_2 drawn out of the atmosphere and transferred to the deep ocean for long-term storage.

PACE data will aid in the development of state-of-the-art computer programs that capture and forecast trends in specific phytoplankton groups. The NASA Goddard Modeling and Assimilation Office, for example, maintains a global ocean biogeochemical model coupled with an ocean–atmosphere algorithm that simulates light's behavior, which is now being refined to take advantage of PACE's high spectral resolution. Using emerging tools such as this, local, state, federal and international agencies—as well as the general public—will be able to make more informed and robust decisions about marine resources. Specifically, PACE data will help build tools to better predict the timing, duration, and extent of algal blooms, including the ability to distinguish between helpful species that fuel our ocean's food resources and their "evil twins," toxic and harmful algae, as well as the fate of these blooms and their role in Earth's global carbon cycle.